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Evaluation of Subjective Thermal Strain in Different Kitchen Working Environments Using Subjective Judgment Scales

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Abstract: To elucidate the subjective thermal strain of workers in kitchen working environments, we performed a cross-sectional study involving 991 workers in 126 kitchen facilities in Japan, using a self-reporting questionnaire survey and subjective judgment scales (SJS). The ambient temperature, mean radiant temperature (MRT), and wet-bulb globe temperature (WBGT) index were measured in 10 kitchen facilities of the 126 kitchens. The association of SJS with the types of kitchen was estimated by multiple logistic regression models. Of the 991 kitchen workers, 809 (81%) responded to the questionnaire survey. Compared with the electric kitchens, the proportion of workers who perceived the room temperature as hot to very hot was significantly higher, and the ambient temperature, MRT, and WBGT were significantly higher in the gas kitchens. Compared with the electric kitchens, workers in gas kitchens had a more than fivefold (males) and tenfold (females) higher SJS adjusted for confounding factors (male odds ratio (OR), 5.13; 95% confidence interval (CI), 1.65–15.9; and female OR, 10.9; 95%CI, 3.89–30.5). Although SJS was affected by some confounding factors, our results suggest that workers in gas kitchens might be exposed to a higher heat strains than those in electric kitchens.

Key words: Subjective thermal strain, Subjective judgment scales, Kitchen work, Glove temperature, WBGT

Introduction

The thermal strain of work environments is related to the health status of workers, being associated with acute heat stroke, heat disorder, and blood circulation problems[1–3], and can cause unsafe conditions, discomfort, affect performance, and harm the health of employees in heat-associated industries[2,4,5]. In order to protect workers from the severest effects of thermal strain, numerous measurements such as the wet-bulb globe temperature (WBGT) index, which is a useful evaluation index for hot environments, have been adopted widely in many countries, leading to the recommendation of threshold limit values in the USA[6,7] and Japan[8].

Because of the difference in individual tolerance to

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heat, exposure time, clothes, working intensity, gender, and age[4)], workers' subjective feelings are viewed as an important evaluation item regarding thermal strain under working conditions[9, 10)]. People's subjective feelings about thermal strain have been reported using certain subjective assessments in some industries excluding food services[9, 11, 12)]. Since 1995, subjective judgment scales have been proposed by the International Organization for Standardization (ISO 10551)[13)].

On the other hand, kitchen work has been reported to involve a marked workload and hazards to health[14–17, 27)]. With regard to the environment, kitchens showed a higher ambient temperature as one of the typical workplaces of hot indoor environments in previous studies[10, 17, 18)]. In recent years, environmental improvements due to the introduction of electric instead of gas kitchens have also been reported in the food service industry[19)]. To the best of our knowledge, no study has been conducted to evaluate thermal strain using subjective judgment scales in kitchen work. Herein, we hypothesized that a difference in thermal strain between 2 types of kitchen would be an independent factor of subjective thermal strain confounded by factors such as personal, work-related, and other environmental factors.

The purpose of the present study was to elucidate the thermal strain loaded on kitchen workers in the actual gas or electric kitchens using subjective judgment scales in different kitchen environments.

Method

Study design, subjects, and survey

A cross-sectional study design and field measurements were used. The subjects were 991 workers recruited from 126 kitchen facilities in 103 primary schools (81.7%), 17 hospitals (13.5%), and 6 restaurants (4.8%) in central Japan. The first questionnaire survey was conducted involving all workers of the 126 kitchens in August to November 2006. This self-reporting questionnaire survey assessed workers' gender, age, height, weight, and work-related factors such as years of employment, working hours, working system, shift, and type of main job. The body mass index (BMI) was calculated as the body weight (kg) divided by the square of the height (m^2). With regard to subjective thermal strain, based on ISO 10551 (1995)[13)], assessment of the thermal environment using subjective judgment scales (SJS) was employed to estimate the thermal strain of the working environment in the kitchen. The magnitude of thermal strain was evaluated by classifying the SJS into seven scales: "very cold", "cold", "slightly cold", "neutral", "slightly hot", "hot", and "very hot", represented by "–3", "–2", "–1", "0", "+1", "+2", and "+3" of the visual analogue scale, respectively. In this study, some cells of "very cold" and "cold" were 0%, so we combined "very cold", "cold", and "slightly cold" into one level. The second questionnaire survey was applied to investigate kitchen environmental factors such as the area and ceiling height of the kitchen, presence/absence of an exhaust hood, ventilation fan, and air conditioner, type of floor condition, and output per day (meals/day) for administrators of the 126 kitchen facilities. All data were collected using an anonymous mailed questionnaire.

Environmental measurement

Of the 126 kitchens facilities, measurements of environmental conditions were conducted in 5 electric and 5 gas kitchens. These field measurements were carried out from August 26 to November 11 in Tokyo, Tochigi, and Saitama located in the east area of Japan. The ambient dry-bulb temperature (Ta, ˚C), relative humidity (RH, %), air-flow velocities (Va, m/s), and globe temperature (Tg, ˚C) surrounding the main heating appliances such as the kettle, oven, and stove were digitally recorded once every minute using portable predicted mean vote (PMV) meters (AM-101, Kyoto Electronics Manufacturing Co., Ltd., Kyoto, Japan) positioned at height of 140 cm from the floor and approximately 20–30 cm away from the heating appliances (Fig. 1). In this study, according to ISO 7726 and 7243[8, 13)], the mean radiant temperature (MRT, ˚C) and wet bulb globe temperature (WBGT, ˚C) index values were calculated using the following equations:

$$MRT = (Tg + 273)^4 + (1.1 \times 10^8 \times Va0.6)\ (Tg–Ta) / (\varepsilon g \times D^{0.4})]^{1/4} - 273$$

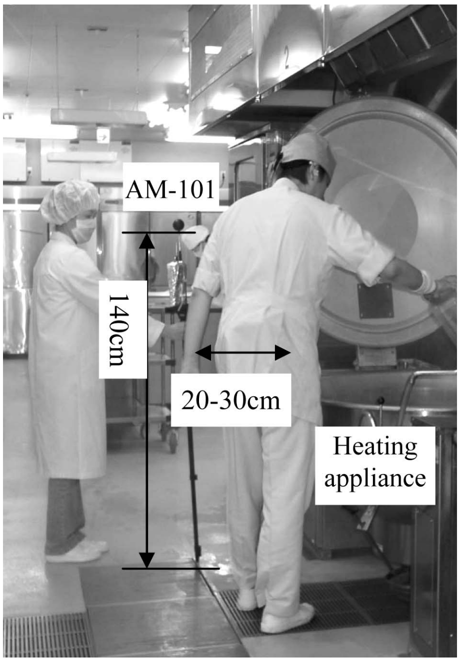

Fig. 1. The position of PMV meters (AM-101).

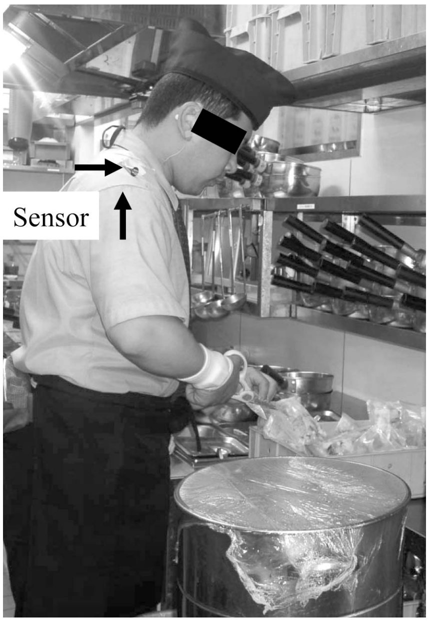

Fig. 2. The sensor of Thermo Recorders (TR-52).

In the above equation, Tg denotes the globe temperature; Ta, ambient dry-bulb temperature; Va, air-flow velocity; εg, D, diameter of globe.

$$WBGT = 0.7\ Tw + 0.3\ Ta$$

In the above equation, Tw denotes the natural wet-bulb temperature. In this study, it was not measured directly but was estimated from Ta and RH.

Of the 10 kitchens, 11 workers in electric kitchens and 13 workers in gas kitchens were assessed regarding the thermal condition they were subjected to. The ambient temperature (˚C) was digitally recorded once every 30 s using Thermo Recorders (TR-52, T&D Co., Ltd., Nagano, Japan) fixed to the right shoulders of the workers whose height range from 168 cm to 183 cm (Fig. 2).

This study was approved by the Ethics Committee of Dokkyo Medical University. All subjects were fully informed of the purpose of the study, and then gave written informed consent.

Statistical analysis

The variables of the survey were re-categorized as follows: age (<35/35–55/55≤yr), BMI (<25/25≤kg/m^2), years of employment (<3/3≤yr), working hours (<8/8/8≤h), working system (regular/part-time), shift (day shift/split shift/other), type of main job (cooking/washing up/other), production level (<750/750≤meals per day), size of kitchen (<200/200≤m^2), ceiling height (<3/3≤m), exhaust hood (yes/no), fan or air conditioner (yes/no), and type of floor condition (wet/semi-dry/dry). The χ^2 test and Mann-Whitney U test were used, as appropriate, to compare SJS, personal characteristics, work-related, and kitchen environmental factors, MRT, WBGT, and the ambient temperature between the electric and gas kitchens.

To analyze the association between SJS and each factor, the subjective judgment scale was divided into two levels: a high level of subjective thermal strain (from +2 to +3), and low level of subjective thermal strain (from –3 to +1). Simple logistic regression (independent variable=the levels of SJS, dependent variables=personal characteristics or job-related or kitchen environmental factors) were used. To analyze the association of the levels of SJS with the type of kitchen allowing for significant confounding factors obtained through simple logistic regression, Model 1 was adjusted for age, Model 2 involved work-related factors such as years of employment, working hours, working system, and type of main job. Model 3 involved kitchen-based environmental factors such as the size of the kitchen, ceiling height, exhaust, type of floor condition, and type of kitchen, and Model 4 was adjusted for all factors by multiple logistic regression models.

Values of $p<0.05$ were considered significant with the two-sided test. The SPSS 16.0J package (SPSS Inc., Tokyo, Japan) for Windows was used for all statistical analyses.

Results

Of the 991 kitchen workers, 809 workers (179 males and 630 females) responded, giving a response rate of 81.6%. The mean age was 37.5 (SD 12.4) for males and 42.4 (SD 11.4) for females. Among the 809 responders, the workers with missing values, expressed as a percentage, were as follows: weight (1.2%), years of employment (6.1%), working hours (2.1%), working system (2.5%), shift (2.5%), production level (5.1%), exhaust hood (12.4%), fan (4.3%), air conditioner (4.1%), and type of floor condition (4.1%).

Environmental conditions of electric and gas kitchens

Figure 3 shows the ambient temperature (a), MRT, and WBGT index (b–d) as the mean (standard deviation). The mean ambient temperature (a) surrounding cooks in gas kitchens was significantly higher than that in electric kitchens; 29.6 (SD 2.2) ˚C vs. 25.7 (SD 2.4) ˚C, respectively. The means of MRT around the kettle (b), oven (c), and stove (d) in the gas kitchens were significantly higher than those in electric kitchens: (b) 36.4 (SD 7.0) ˚C vs. 24.8 (SD 2.5) ˚C ($p<0.001$), (c) 44.9 (SD 14.3) ˚C vs. 39.5 (SD 11.6) ˚C ($p<0.001$), and (d) 38.1 (SD 5.4) ˚C vs. 27.1 (SD 6.5) ˚C ($p<0.001$), respectively. The means of the WBGT index around the kettle (b), oven (c), and stove (d) in the gas kitchens were significantly higher than those in electric kitchens: (b) 24.6 (SD 2.2)

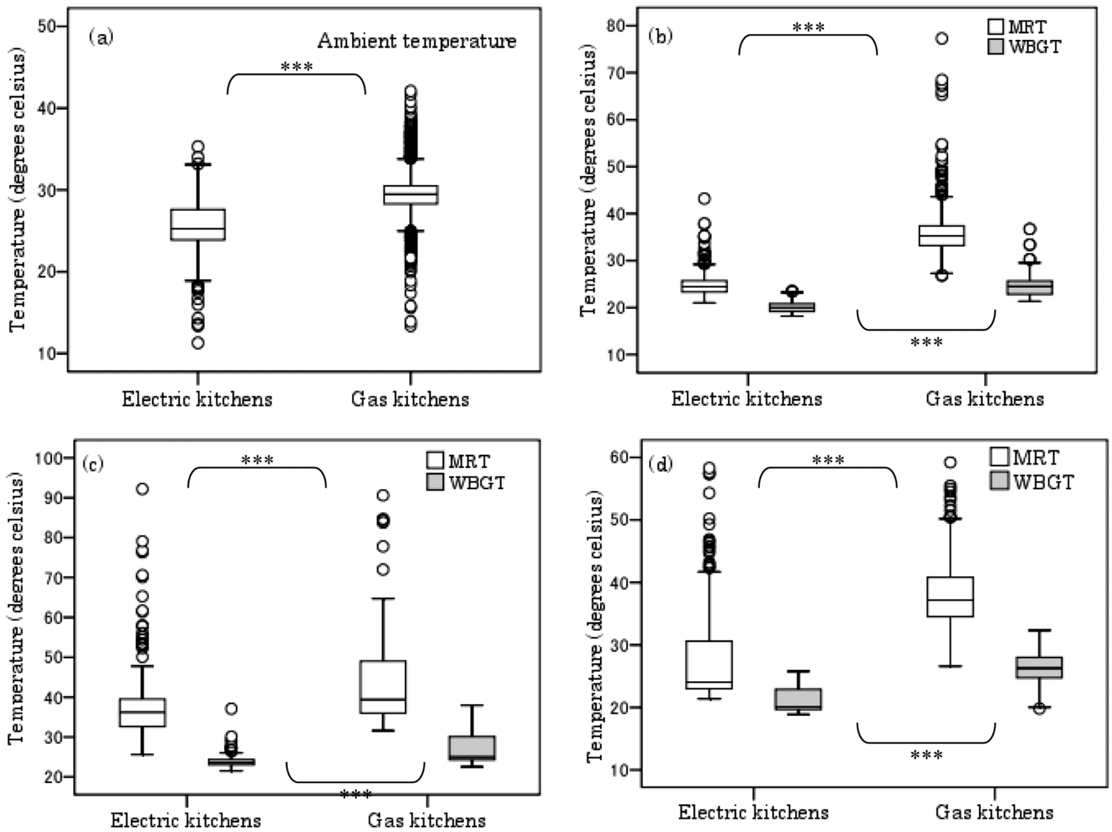

Fig. 3. Comparison of environmental conditions between electric and gas kitchens.
(a): Ambient temperature surrounding the cook, (b): Temperatures surrounding the kettle, (c): Temperatures surrounding the oven, (d): Temperatures surrounding the stove.
****p*-value is less than 0.001 using Mann-Whitney U test.

˚C vs. 20.0 (SD 1.2) ˚C (p<0.001), (c) 26.7 (SD 3.7) ˚C vs. 24.1 (SD 2.0) ˚C (p<0.001), and (d) 26.0 (SD 2.3) ˚C vs. 21.0 (SD 1.8) ˚C (p<0.001), respectively. Compared with electric kitchens, the environments of the worker in gas kitchens were smaller, had a lower ceiling height, and a wetter floor condition (Table 1).

Characteristics of subjects and facilities in electric and gas kitchens

Table 2 summarizes the difference between the two types of kitchen. The percentages of male workers, those working less than 3 yr, and part-time workers in the gas kitchens were lower than those in electric kitchens. The percentages of those who were 55 yr old or over, working 8 h per day, and cooking in the gas kitchens were higher than those in the electric kitchens.

SJS of subjects between electric and gas kitchens

Figure 4 shows that kitchen workers experienced a significant difference in SJS between electric and gas kitchens by gender. The proportion of workers who perceived the room temperature as higher SJS (from hot to very hot) was significantly higher in gas than in the electric kitchens among males (52.1% vs. 11.8%, respectively) and females (63.5% vs. 12.1%, respectively).

Association of SJS with each factor

The association of SJS with personal, work-related, and kitchen-based environmental factors is shown in Table 3. A high SJS was associated with age (≥55 yr), years of employment (≥3 yr), working hours (8 h), regular occupation, cooking job, a smaller size of kitchen (<200 m^2), and no exhaust hood for females, hospital and restaurant kitchen for males, and a lower ceiling height (<3 m), semi-wet and wet floor condition, and gas kitchen for males and females.

Association of SJS with types of kitchen

Table 4 shows the odds ratio (OR) and 95% confidence interval (CI) in models. Model 1 was adjusted for age. Compared with the electric kitchens, workers in gas kitchens had a higher level of SJS (total OR, 11.6; 95%CI, 8.07–16.8; male OR, 9.04; 95%CI, 3.81–19.0; and female OR, 12.8; 95%CI, 8.41–19.6). Model 2 was adjusted for

Table 1. Characteristics of the kitchen workers with environmental factors

	Total	Electric kitchens		Gas kitchens		p-value[a]
	n	n	(%)	n	(%)	
Environmental factor						
Size of kitchen (m^2)						
≥200	456	296	(69.6)	160	(41.7)	<0.001
<200	353	129	(30.4)	224	(58.3)	
Ceiling height (m)						
≥3	305	229	(53.9)	76	(19.8)	<0.001
<3	504	196	(46.1)	308	(80.2)	
Exhaust hood						
Yes	627	344	(89.4)	283	(87.3)	0.406
No	82	41	(10.6)	41	(12.7)	
Air conditioner or fan						
Yes	731	388	(95.3)	343	(97.7)	0.080
No	27	19	(4.7)	8	(2.3)	
Type of floor condition						
Dry	474	399	(93.9)	75	(21.4)	
Semi-wet	117	16	(3.8)	101	(28.8)	<0.001
Wet	185	10	(2.4)	175	(49.9)	
Type of kitchen						
School	433	225	(52.9)	208	(54.2)	
Hospital	318	167	(39.3)	151	(39.3)	0.799
Restaurant	58	33	(7.8)	25	(6.5)	

[a]: p-value from χ^2 test.

age and work-related factors (years of employment, type of main job, working hours and system), and male OR, 11.9; 95%CI, 4.80–29.0 was increased more than in model 1; female OR, 9.75; 95%CI, 5.71–16.7) were decreased more than in Model 1. Conversely, ORs (total OR, 5.97; 95%CI, 3.40–10.5; male OR, 3.61; 95%CI, 1.41–9.28; female OR, 10.3; 95%CI, 4.49–23.1) adjusted for age and kitchen environmental factors (size of kitchen, ceiling height, exhaust hood, floor condition and type of kitchen) in Model 3 were decreased more than in Model 1. Model 4 was adjusted for all factors, and ORs (total OR, 6.60; 95%CI, 3.41–12.8; male OR, 5.13; 95%CI, 1.65–15.9; female OR, 10.9; 95%CI, 3.89–30.5) showed a more than fivefold higher level of SJS in gas kitchens.

Discussion

To the best of our knowledge, this is the first study to evaluate the subjective judgment scales of ISO (10511) in kitchen work, and we found that the subjective judgment scales revealed significant variations difference between different heat sources in the kitchen; the SJS level in the gas kitchen was significantly higher than that in the electric kitchen. The multiple logistic regression models suggest that a hot kitchen environment would be likely to be an independent factor with many confounding factors under real-life working conditions. Compared with electric kitchens, workers in gas kitchens showed a more than fivefold higher SJS in males, and more than tenfold higher SJS in females.

These results are supported by the following. First, Ito[10, 17] reported a higher Ta in gas kitchens, and Koda[20] reported that Ta surrounding a kettle can be raised to 33˚C. In the present study, the measured ambient temperature value in the gas kitchen was 29.6˚C, and the WBGT index and MRT surrounding the kettle were 24.6˚C and 36.4˚C, respectively, consistent with previous studies. In our experimental trial[21], the gas stove showed many changes in Ta, Tg, the radiant heat index (a difference between ambient dry-bulb temperature and globe temperature), and WBGT index after 30-min heating compared with the inducting heating (IH) stove with high energy efficiency; and the radiant heat index (a difference of 1.5–10.6˚C) and WBGT index (a difference of 0.5–3.5˚C) were higher with gas compared to IH appliances. In the actual kitchens in the present study, we measured a higher MRT (a difference of 5.5–11.6˚C) and WBGT index (a difference of 2.6–5.8˚C) in front of the gas kettle, oven, and stove in gas kitchens compared with the same type of IH appliances in electric kitchens, and

Table 2. Personal and work-related characteristics of the kitchen workers

	Total	Electric kitchens		Gas kitchens		p-value[a]
	n	n	(%)	n	(%)	
Personal factors						
Gender						
Males	179	110	(25.9)	69	(18.0)	0.007
Females	630	315	(74.1)	315	(82.0)	
Age (yr)						
≤35	231	127	(30.4)	104	(27.3)	
35–55	442	244	(58.4)	198	(52.0)	0.001
≥55	126	47	(11.2)	79	(20.7)	
BMI (kg/m^2)						
<25.0	649	330	(84.6)	319	(86.2)	0.532
≥25.0	111	60	(15.4)	51	(13.8)	
Work-related factors						
Years of employment (yr)						
<3	154	125	(35.0)	29	(8.3)	<0.001
≥3	554	232	(65.0)	322	(91.7)	
Working hours (h/d)						
<8	248	182	(43.8)	66	(17.6)	
8	456	171	(41.1)	285	(75.8)	<0.001
>8	88	63	(15.1)	25	(6.6)	
Working system						
Part-time	292	216	(52.6)	76	(20.1)	<0.001
Regular	497	195	(47.4)	302	(79.9)	
Shift						
Day service	588	313	(76.3)	275	(74.1)	
Day shift	176	86	(21.9)	90	(24.3)	0.354
Other	17	11	(2.7)	6	(1.6)	
Type of main job						
Cooking	365	155	(36.5)	210	(54.5)	
Washing up	68	42	(9.9)	26	(6.8)	<0.001
Other	376	228	(53.6)	148	(38.5)	
Output (meals/d)						
<750	418	195	(45.9)	223	(58.1)	0.001
≥750	391	203	(54.1)	161	(41.9)	

[a]: p-value from χ^2 test.

the cooks in the gas kitchens felt a higher ambient temperature (a difference of 3.9˚C) during cooking compared with those in the electric kitchens. To avoid the impacts of outdoor air temperature in the middle of summer, the present study was conducted starting from the end of August. The outdoor air temperature was at 17˚C to 30˚C excluding one day at 33˚C (data not shown). According to exposure to different heat sources, thermal strains in gas kitchens is greater than in electric kitchens. Therefore, this hot environment may have a major impact on the level of SJS of workers.

Secondly, as previously reported, 60% of the workers felt hot and very hot at 25 to 29˚C, and 30% felt these at 21 to 27˚C of Ta in offices[11]. Yoshino[9] reported an association between heat strains (20 to 35˚C) and thermal sensitivity in an experimental trial. We also observed that the percentage of subjects who felt "considerably hot" in their abdomen and hands was higher for those using gas stoves than IH stoves[21]. Although different subjective judgment scales were used in previous studies, these reported results were consistent with our findings. The level of SJS showed that the subjective feelings of workers might represent the magnitude of thermal strain in the environment.

Thirdly, although we found that the different heat sources in the kitchen were associated with the level of

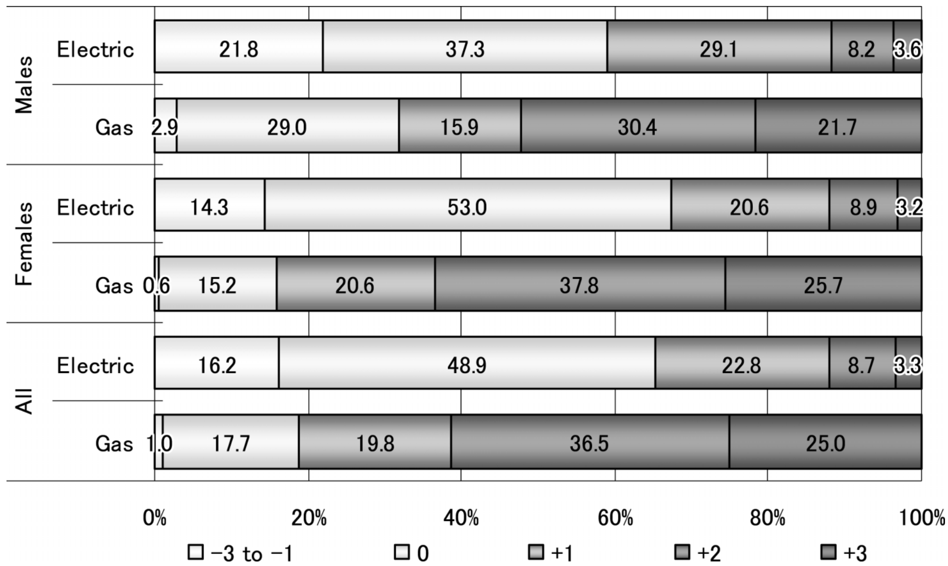

Fig. 4. The percentage levels of subjective judgment scales (SJS) by the types of kitchen.
–3 to –1: very cold to slightly cold; 0: neutral; +1: slightly hot; +2: hot; +3: very hot.

SJS, other factors such as age, period of employment, working hours, shift, cooking work, and size of the kitchen for females, and the type of floor condition, ceiling height, and type of kitchen for males and females were also associated with the SJS in single logistic regression analysis. To examine these confounding factors, we used multiple logistic regression models to analyze the association of SJS with the type of kitchen. Consequently, workers in gas kitchens had a more than sevenfold higher SJS compared with those in the electric kitchens after adjustments for age, BMI, work-related, and environmental factors. Heat loads derived from IH were lower than from gas equipment after mock cooking in some experimental trials[21–23]. Then, the gas kitchen as a hot environment would be considered an independent factor, although the level of SJS was confounded by personal, work-related, and environmental factors. Thus, the levels of SJS would be likely to represent the severity of hot environments.

In the present study, compared with electric kitchens, female workers in gas kitchens experienced twofold higher SJS than males. Previous studies[24, 25] showed that women had lower levels of perspiration and heat tolerance, and a higher heart rate and rectal and skin temperatures than males, particularly when physical work was required, and elderly persons also showed the same results[24, 26]. In the present study, both males and females were exposed to the same work load and heat stress in the kitchen working environment, and there were more females than males over the age of 55 yr. Our study showed the females workers had a higher odds ratio of SJS in gas kitchens (Table 4). Therefore, much of the difference in SJS would be estimated to relate to elderly women's relatively low level of physical fitness and lack of heat acclimatization. As a result, females responded to a higher SJS compared to males in the present study.

The strength of this study was that the sample size was large, and there was a high response rate (81%). The level of subjective thermal strain was measured using the subjective judgment scales of ISO (10511). In additions, environmental conditions were measured in 10 facilities including school, hospital, and restaurant kitchens, where different magnitudes of heat strains generated by gas and electric kitchens were identified by the MRT and WBGT index. Therefore, subjective judgment scales are considered to show a higher internal validity in the evaluation of heat strains. So the finding of the present study indicates that the subjective judgment scales of ISO 10511 is a simple evaluation tool for environmental conditions without using a measuring device, and can represent environmental sensation from cold to hot with 7 scales. Therefore, it should be regarded as a feasible one for assessing the heat working environment.

There are several limitations in this study. The horizontal diffusion of steam or soot produced in the course of cooking is reported to be faster in the IH stove than in the gas stove[28, 29], and such factors were not examined in this study. So we cannot simply conclude from the results of this study that IH stove is better than gas stove. With regard to external validity of this study, there are also several limitations, so we should be careful in generalizing the result of this study. First, the 126 kitchen facilities were not selected by random sampling, and 80% of the facilities of were school kitchen. Second, 77.9%

Table 3. Association of subjective judgment scales (SJS) with each factor using simple logistic regression

	Total		Male		Female	
	Odds ratio	95%CI	Odds ratio	95%CI	Odds ratio	95%CI
Personal factors						
Age (yr)						
≤35	1.00		1.00		1.00	
35–55	1.39	0.99–1.97	1.12	0.55–2.29	1.40	0.93–2.10
≥55	2.32	1.48–3.65	1.71	0.62–4.72	2.37	1.41–3.97
BMI (kg/m^2)						
<25.0	1.00		1.00		1.00	
≥25.0	0.99	0.65–1.50	1.40	0.65–3.02	0.94	0.56–1.56
Work-related factors						
Years of employment (yr)						
<3	1.00		1.00		1.00	
≥3	3.47	2.21–5.43	1.06	0.45–2.48	5.05	2.95–8.64
Working hours (h/d)						
<8	1.00		1.00		1.00	
8	2.68	1.89–3.79	0.81	0.35–1.84	3.49	2.37–5.12
>8	0.47	0.47–1.53	0.98	0.38–2.50	0.44	0.17–1.19
Working system						
Part-time	1.00		1.00		1.00	
Regular	2.76	1.99–3.84	1.21	0.57–2.59	3.5	2.42–5.06
Shift						
Other	1.00		1.00		1.00	
Day service	1.08	0.34–3.50	1.36	0.24–7.67	1.03	0.21–5.16
Day shift	2.09	0.67–6.48	0.75	0.14–4.08	3.01	0.63–14.3
Type of main job						
Other	1.00		1.00		1.00	
Washing up	1.15	0.64–2.05	0.47	0.05–4.12	1.26	0.68–2.31
Cooking	2.67	1.95–3.64	1.14	0.58–2.25	3.57	2.50–5.09
Output (meals/d)						
<750	1.00		1.00		1.00	
≥750	0.96	0.72–1.29	1.31	0.68–2.53	0.90	0.66–1.25
Environmental factors						
Size of kitchen (m^2)						
≥200	1.00		1.00		1.00	
<200	2.30	1.71–3.08	1.44	0.74–2.80	2.53	1.82–3.52
Ceiling height (m)						
≥3	1.00		1.00		1.00	
<3	2.54	1.84–3.50	5.15	1.91–13.9	2.43	1.72–3.44
Exhaust hood						
Yes	1.00		1.00		1.00	
No	1.72	1.08–2.74	—	—	1.99	1.21–3.26
Air conditioner or fan						
Yes	1.00		1.00		1.00	
No	0.40	0.15–1.07	—	—	0.47	0.17–1.30
Type of floor condition						
Dry	1.00		1.00		1.00	
Semi-wet	5.58	3.59–8.68	2.81	1.08–7.30	7.13	4.28–11.9
Wet	17.2	11.3–26.1	16.2	6.59–39.9	17.4	10.8–27.9
Type of kitchen						
School	1.00		1.00		1.00	
Hospital	0.44	0.32–0.60	17.73	2.33–135.2	0.31	0.21–0.45
Restaurant	1.19	0.69–2.06	28.08	3.52–223.7	1.74	0.61–4.98
Heat source of kitchen						
Electric	1.00		1.00		1.00	
Gas	11.80	8.18–16.7	8.14	3.86–17.2	12.70	8.42–19.1

Table 4. Association of subjective judgment scales (SJS) with types of kitchen using multiple logistic regression models

	Total		Males		Females	
	Odds ratio	95%CI	Odds ratio	95%CI	Odds ratio	95%CI
Model 1						
Electric kitchens	1.00		1.00		1.00	
Gas kitchens	11.6	8.07–16.8	9.04	3.81–19.0	12.8	8.41–19.6
Model 2						
Electric kitchens	1.00		1.00		1.00	
Gas kitchens	10.8	6.90–16.8	11.9	4.80–29.0	9.75	5.71–16.7
Model 3						
Electric kitchens	1.00		1.00		1.00	
Gas kitchens	5.97	3.40–10.5	3.61	1.41–9.28	10.3	4.49–23.7
Model 4						
Electric kitchens	1.00		1.00		1.00	
Gas kitchens	6.60	3.41–12.8	5.13	1.65–15.9	10.9	3.89–30.5

Model 1 was adjusted for age.
Model 2 was adjusted for age, and work-related factors.
Model 3 was adjusted for age, and kitchen-based environmental factors.
Model 4 was adjusted for age, work-related, and kitchen-based environmental factors.

of kitchen workers were female; therefore, sampling bias might have affected the results. However, all workers in these kitchens were recruited as subjects; there were no differences in the percentage of subjects among types of kitchen between electric and gas kitchens. Considering the influence of gender, analyses were conducted separately by gender. Excluding some confounding factors, there was a tendency regarding SJS between males and females. Third, worker's metabolic rate and clothing they wear both of which influence SJS are not examined in this study.

In conclusion, according to exposure to different heat sources, subjective thermal strain seemed to be an effective method to evaluate hot environments, corresponding to the results of environmental measurements. Although subjective evaluation is related to some confounding factors, our results suggest that workers in gas kitchens were subjected to a higher thermal strain than those in electric kitchens.

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